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Radiation Safety at Nuclear Power Plants: Studies Look at Public, Workers

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Key Facts

■ Workers at U.S. facilities that use radioactive materials are subjected to a small occupational health risk. The Nuclear Regulatory Commission sets standards to ensure their safety. The agency limits worker doses to no more than five rem (5,000 millirems)¹ per year and requires that occupational doses be kept “as low as reasonably achievable.” Radiation workers are individually monitored to record their total radiation dose. Utilities maintain detailed exposure records and report those records annually to the NRC and the workers.

■ Occupational doses in the U.S. nuclear energy industry averaged only 106 millirems per worker in 2001—about one-tenth of the 900 millirems per year dose of cosmic radiation received by airline pilots

and cabin crews who regularly fly the high-altitude New York-Tokyo route.

■ People living near a nuclear power plant are exposed to only a tiny amount of radiation from the facility. Less than 1 percent of the average person’s total exposure comes from nuclear power plants.

■ Radiation is easily detected and is one of the most studied and best understood forms of energy. Many organizations and scientists in the United States and internationally have extensively studied the health effects of radiation exposure. The results of these studies form the scientific basis for radiation safety standards to protect workers and the public.

■ Among organizations that are chartered to conduct ongoing studies are the United Nations Scientific Committee on the Effects of Atomic Radiation, the National Academy of Sciences/National Research Council, the International Agency for Research on Cancer, and the National Cancer Institute. Further studies will continue to expand the knowledge base on radiation health effects.

Studies of Radiation Health Effects on Public Near Nuclear Power Plants

Although nuclear power plants represent one of the smallest sources of radiation to which the public is exposed, a large number of scientific studies have been carried out to ensure that they are not a risk to people living nearby.

Several uncertainties are inherent in any study of the effects of radiation. First, it is extremely difficult to identify an appropriate control group of unexposed individuals who are otherwise identical to the exposed population. Second, there are likely to be “confounding variables” among the exposed population—like exposure to chemicals or cigarette smoke—which are linked to health problems and therefore complicate data interpretation. Third, it is often difficult to determine the exact radiation doses to individuals in the exposed group. For these reasons, it is necessary to carefully scrutinize the methodology of studies whose conclusions deviate from the general scientific consensus about the effects of radiation.

¹ Exposure to radiation is called “dose” and is expressed in the measures rem and millirems. A rem measures the effect of radiation on the human body. It takes into account both the amount of radiation deposited in body tissues and the type of radiation. A millirem is a thousandth of a rem. The average person receives about 20 millirems from a chest X-ray.

Radiation Safety at Nuclear Power Plants: Studies Look at Public, Workers

Page 2 of 8—October 2003

Scientific studies include the following:

National Cancer Institute Study. In September 1990, the National Cancer Institute (NCI) of the National Institutes of Health announced that a large-scale study found no increased incidence of cancer mortality for people living near 62 nuclear installations in the United States. The research, which evaluated mortality from 16 types of cancer, showed no increase in the incidence of childhood leukemia mortality in the study of surrounding counties after start-up of the nuclear facilities. The NCI study, the broadest of its kind ever conducted, was initiated in 1987, partly in response to a study by the United Kingdom's Office of Population Censuses and Surveys (see below). The NCI surveyed 900,000 cancer deaths in counties near nuclear facilities that had operated for at least five years prior to the start of the study—the minimum time considered sufficient for related health effects to appear.

British Studies. A study by the U.K. Office of Population Censuses and Surveys (OPCS) showed no rise in cancer near nuclear installations in England and Wales—either for young persons or adults—even when focusing on types of cancer particularly associated with exposure to ionizing radiation, such as leukemia, bone cancer and multiple myeloma.

Investigators analyzed eight million separate occurrences of cancer from 1959 to 1980, taking into account the distances from nuclear facilities. A follow-up analysis of the OPCS data by Sir Richard Doll of Oxford University confirmed nearly all of the initial findings but detected a small excess of childhood leukemia and Hodgkin's disease near older U.K. nuclear sites.

The Oxford researchers said the apparent excess appeared to result from comparisons with control areas that had particularly low cancer mortality, but they suggested additional study.

French Study. A study by two French researchers—reported in the Oct. 25, 1990, issue of *Nature*—found no increase in childhood leukemia near six nuclear installations in France between 1968 and 1987. The facilities included four nuclear power plants and the nuclear fuel reprocessing plants at La Hague and Marcoule.

Canadian Study. A study released in 1991 by the Ontario Cancer Treatment and Research Foundation, commissioned by Canada's Atomic Energy Control Board, found no statistically significant increase in leukemia among children born to mothers living near five nuclear sites in Ontario province.

Researchers examined data for 1,894 children 14 years or younger who died from leukemia between 1950 and 1987 and who lived within 15 miles of five Canadian nuclear facilities. The facilities were Ontario Power Generation's Pickering and Bruce Power's Bruce nuclear power plants, the Elliot Lake uranium mines and mills, Atomic Energy of Canada Ltd.'s Chalk River nuclear laboratories, and a former 20-megawatt nuclear station at Rolphton. Near the Chalk River laboratories, childhood leukemia was one-third of the expected rate. Near the Pickering power station, there were 33 childhood leukemia deaths between 1971 and 1987, more than the 25 statistically expected. However, the rate was also elevated during the 20 years before the station entered service.

West Valley Study. A study by doctors at the University of Buffalo Medical School found no increase in cancer incidence among people living in seven towns near a former nuclear fuel reprocessing plant at West Valley in western New York state. In fact, a slight reduction in cancer incidence was observed. The study covered 1973 to 1983.

Pennsylvania Department of Health Studies. Two studies issued in 1991 by the Pennsylvania State Department of Health show no rise in cancer incidence among people living

Radiation Safety at Nuclear Power Plants: Studies Look at Public, Workers

Page 3 of 8—October 2003

near the Three Mile Island nuclear plant. One study involved 31,000 people living within a five-mile radius of the plant. While 943 cases of cancer would be expected to have occurred among the group from 1982 to 1989, only 813 were recorded, the study showed.

The second study involved 5,292 women of childbearing age living within a 10-mile radius of the plant. Among this group, 36 cases of cancer could have been expected; 35 were recorded. The state study found no association between radiation and cancer, and no association between psychological stress and cancer.

TMI Health Fund Study. A study by researchers at Columbia University, released in 1990, found no association between the release of radiation during the 1979 Three Mile Island accident and leukemia or childhood cancer in general. The study, requested by public stakeholder groups near the plant and funded by the Three Mile Island Public Health Fund, examined cancer incidence among 159,684 people living within 10 miles of the plant.

More than a dozen other major health studies have found no link between cancer and radiation released from TMI during the accident. The only health effect linked to the accident was stress.

Pilgrim Study. In 1990, the Massachusetts Department of Public Health (MDPH) published a study (the “Southeastern Massachusetts Health Study”) of leukemia incidence for 22 towns in the southeastern area of the state. The purpose of the study was to determine if the incidence of leukemia could be associated with exposure to radiation from the Pilgrim nuclear power plant. The population studied consisted of people aged 13 years and older who were diagnosed between 1978 and 1986 with any type of leukemia, excluding one type known not to be associated with radiation.

The report’s findings included the following:

- Individuals with the highest potential for exposure to radiation emissions from Pilgrim (i.e., those who lived and/or worked the longest and closest to the plant) had almost four times the incidence of leukemia as those having the lowest potential for exposure (i.e., those who lived and/or worked the least amount of time and farthest from the plant).
- An association between radiation released from the Pilgrim plant and leukemia incidence was found only among those cases diagnosed before 1984.

- No apparent relationship with the plant was observed for cases diagnosed between 1984 and 1986.

A review of the study, released in October 1992, found serious problems with the study’s methods and conclusions. The 16-month-long analysis was the work of an independent review panel, composed of six experts in epidemiology, appointed by MDPH and Boston Edison Co., which owned the Pilgrim plant.

Among the most serious flaws in methodology, according to the panel, were the following:

- There was a large disparity between the number of excess leukemia cases reported by the study (47) and the number to be expected using data from other radiation studies (0.52).
- The study failed to document, from vital records, any excess leukemia deaths during the study period, compared with leukemia mortality before the Pilgrim plant opened.
- The study failed to include towns on Cape Cod that were within the study area.
- In estimating how much radiation was received by people living near the plant, the study should have used alternative models of how radiation is dispersed.

The panel called for “a carefully designed new study” to

Radiation Safety at Nuclear Power Plants: Studies Look at Public, Workers

Page 4 of 8—October 2003

address the concerns raised in its report.

Greenpeace Study. “Nuclear Power, Human Health and the Environment: The Breast Cancer Warning in the Great Lakes Basin” was released in 1995 by Greenpeace and Ernest Sternglass, an anti-nuclear activist. The study claims that women in 81 counties in the Great Lakes region, where there are 36 U.S. and Canadian nuclear power plants, have an increased risk of breast cancer mortality. It also claims the 1990 National Cancer Institute (NCI) study and other studies that found no cancer/nuclear power connection failed to look at a sufficiently broad radius around the plants.

The study’s findings and methodology have drawn widespread criticism among scientists and in the news media:

- It provides no evidence that women in the 81 Great Lakes counties live closer to nuclear power plants, or were exposed to significantly higher levels of radiation, than women in nearby counties that Greenpeace did not choose to study.
- No detail is given on important characteristics of the women in those 81 counties, such as urbanization, ethnicity or socioeconomic profile, which would help evaluate whether “selection bias” is present. (The risk of dying from breast cancer is higher in urban areas and among certain ethnic groups.)
- Results can depend on the method used by researchers use to compare data. Greenpeace chose to combine the data for all women in all 81 counties, and compare the total with the U.S. average. The result was 3.2 excess cancer deaths per 100,000 women—an extremely small increase. But if Greenpeace had looked at data from each of the 81 Great Lakes counties individually, it would have found something different: In slightly more than half of the counties, the breast cancer death rates are somewhat lower than the U.S. average, and in slightly less than half of them, the death rates are somewhat higher than the U.S. average. When this method is used, there is no consistent increase in the breast cancer death rates in all of the 81 counties.
- The reason the NCI did not extend its study to a 100-mile radius around each plant—as Greenpeace claims was necessary—is that radioactive emissions from nuclear power plants are virtually nonexistent at that radius. The nearest plant neighbor gets less than one millirem of radiation exposure from the plant annually. This is less than the average

person gets annually from watching television.

Livermore National Laboratory Study. The California Department of Health Services released a study in 1995 comparing cancer rates in children and young adults living near the Lawrence Livermore National Laboratory in Livermore, Calif., with those throughout the rest of Alameda County. The study was commissioned by the federal Centers for Disease Control and Prevention.

Although the study did not find an overall excess of cancer, including leukemia or non-Hodgkin’s lymphoma, young people near Livermore had two to six times as many malignant melanomas (a form of skin cancer) as expected over the 30-year period of the study (1960-1991).

The researchers acknowledge that “differences in community characteristics or health behaviors” might explain this apparent excess. These include the possibility that Livermore residents screened more actively for skin cancer, the fact that the study was not adjusted for socioeconomic status and the fact that Livermore averages more days of sunlight than other areas of the county. (Greater sunlight exposure is thought to be associated with higher risk of melanoma.)

Radiation Safety at Nuclear Power Plants: Studies Look at Public, Workers

Page 5 of 8—October 2003

The study does not assess whether or not melanoma cases had any connection with the Lawrence Livermore National Laboratory.

Wing Re-examination of TMI Data. In 1997, University of North Carolina researcher Steven Wing published a controversial re-evaluation of the data used in the 1990 TMI study, which found no effect on cancer incidence around the plant. Wing claimed more radiation was released during the accident than had been previously reported, resulting in many accident-related cancers within 10 miles of the plant. The authors of the 1990 study, as well as other epidemiologists and the Pennsylvania Department of Health, have criticized Wing's findings and methodology.

Radiation Health Effects Studies of Nuclear Industry Workers

U.K. Study. The January 1992 issue of the *British Medical Journal* published the results of the U.K.'s National Radiological Protection Board's (NRPB) study of 95,000 nuclear workers. The purpose of the study was to assess the effects of low occupational exposure to radiation.

Researchers found that death rates from cancer did not exceed those in the general population. The results of this study were consistent with data from survivors of the atomic

bombs at Hiroshima and Nagasaki, which remain the most important reference for assessing the health effects of radiation. For that reason, the U.K. study was generally believed to confirm the International Commission on Radiation Protection's system of radiation protection. When it released its findings, the NRPB announced plans to do a second study, using a larger study population and longer follow-up.

Gardner Study. A five-year study, conducted by Martin J. Gardner, an epidemiologist and medical statistician at the University of Southampton, England, was published in the February 1990 *British Medical Journal*. Gardner identified a possible association between childhood leukemia in Seascale, England, and the fathers' preconception exposure to radiation while working at the Sellafield nuclear fuel reprocessing plant.

He observed that of 74 cases of childhood leukemia in West Cumbria, 10 of the children had parents who worked at Sellafield. The study also suggested a possible association between the incidence of childhood leukemia in West Cumbria and paternal employment in farming and steel-making, two occupations that involve exposure to chemicals.

The Gardner study's findings are inconsistent with scientific understanding about radiation.

For example, studies of 7,400 children of male Hiroshima and Nagasaki survivors, whose average radiation exposure was four times that of the Sellafield workers, show no evidence of an increase in leukemia or other cancers.

In March, a researcher at Southampton University announced a decision not to pursue Gardner's hypothesis further because numerous studies since 1990 failed to support a radiation-cancer link.

A 1996 report by the U.K.'s Committee on Medical Aspects of Radiation in the Environment (COMARE), which spent more than 10 years examining the Sellafield data, said epidemiologists could stop looking for Gardner's hypothetical radiation-childhood leukemia link at Seascale. "We conclude that the level of risk is inconsistent with the radiation doses actually received via occupational exposure and current estimates of genetic risk," said the report. The results of a study examining the Gardner hypothesis was published in the May 1999 issue of the *British Medical Journal*. In it, the authors concluded that "overall, the findings suggest that the incidence of cancer and leukemia among children of nuclear industry employees is similar to that in the general population."

Radiation Safety at Nuclear Power Plants: Studies Look at Public, Workers

Page 6 of 8—October 2003

Canadian Study. Because of the Gardner findings, a study was conducted in Canada to determine if there were an association between childhood leukemia and the occupational exposure of fathers to radiation prior to the time of the child's conception.

The study was conducted by the Ontario Cancer Treatment and Research Foundation, the University of Toronto and the University of British Columbia for the Atomic Energy Control Board and published in August 1992. The conclusion: "No association between childhood leukemia and the occupational exposures of fathers to ionizing radiation prior to the time of conception."

The report also noted that "the findings of this study in Ontario are not consistent with the hypothesis that childhood leukemia is associated with the occupational exposure of fathers to radiation prior to conception, as was found in the case control study at Sellafield in the United Kingdom by Gardner."

Newcastle Study. An independent study by Professor Alan Craft and Dr. Louise Parker of the Newcastle University Medical School, released in 1992, also contradicted the Gardner study's theory. It found that the geographical distribution of Sellafield employees does not match the geographical distri-

bution of childhood leukemia. This refutes the suggestion that excess leukemia cases in Seascale are due to pre-conception exposure of the Sellafield fathers. The study also showed that in West Cumbria (outside Seascale), where many more children had fathers with higher preconception doses than in Seascale, there was no excess of childhood leukemia.

Kinlen Studies. Two studies published in the *British Medical Journal* in 1993 by Leo Kinlen of the University of Oxford also found "no significant association with paternal pre-conception exposure to radiation as reported by Gardner and colleagues." Kinlen faulted Gardner on several points. First, although the excess cancers were concentrated in Seascale, in West Cumbria, most of the workers at the nearby Sellafield facility lived outside the parish. Second, excess cancers were not limited—as Gardner had thought—to young victims born in Seascale, but also occurred among young Seascale residents who had not been born there. Kinlen believes a more probable cause of the Seascale cancers was "an infectious epidemic promoted by unusual population mixing in an isolated area."

Health and Safety Executive Study. In 1993, the U.K.'s Health and Safety Executive announced the findings of its

three-year investigation of leukemia and non-Hodgkin's lymphoma in the children of men employed at Sellafield from 1950 to 1989. This study, broader and more detailed than Gardner's, found "little evidence to suggest that a father's high preconception radiation dose increases the risk of leukemia and non-Hodgkin's lymphoma for his children." While the study found a childhood leukemia cluster in Seascale, it was confined almost entirely to children whose fathers started work at Sellafield before 1965. The study said this excess could not be attributed to any one cause, although the Kinlen theory of population mixing should be seriously considered.

Doll Review. British epidemiologist Sir Richard Doll dismissed the Gardner hypothesis in a 1994 issue of *Nature*. The Gardner hypothesis had prompted two families to sue British Nuclear Fuels plc, the company that operates Sellafield. They lost the suit in 1993. In his review of the evidence available to the court, Doll said Gardner's theory of radiation-damaged sperm did not accord with what is known about radiation genetics or childhood leukemia. He noted that offspring of Japanese atomic bomb survivors showed no abnormal genetic activity, even though the Japanese survivors had received much higher radiation doses than the Sellafield workers.

Radiation Safety at Nuclear Power Plants: Studies Look at Public, Workers

Page 7 of 8—October 2003

Oak Ridge Study. A study conducted for the Oak Ridge Associated Universities by Steven Wing of the University of North Carolina was published in 1991. The study looked at the 1,524 deaths from all causes among the 8,318 white males hired at Oak Ridge National Laboratory between 1943 and 1972. When compared with all U.S. white males, the Oak Ridge workers had lower than average mortality risks for most causes of death. The study identified 346 cancer deaths among the workers, whereas 438 would normally be expected. The exception was leukemia: Oak Ridge workers were at a 63 percent higher risk of death than all white males. There were 28 deaths from leukemia, whereas 17 would normally be expected.

The same workers had been the subject of an earlier study, which found no increased leukemia risks and no association between cancer mortality and occupational exposures to radiation and other substances. The researchers had no explanation for the difference between the studies. The study does observe an apparent statistical association, but there was insufficient data to conclude that low-level radiation exposure caused the higher than anticipated deaths from leukemia. The study did not take into account possible exposures to hazardous

materials, smoking habits or lifestyles.

Navy Shipyard Workers. A study by researchers at The Johns Hopkins University, released in 1991, found no evidence that the workers who serviced nuclear-powered ships for the U.S. Navy between 1957 and 1981 were harmed by their on-the-job exposure to low levels of radiation.

Commissioned by the U.S. Department of Energy, the study examined the records of 70,000 civilian male workers employed at two private and six naval shipyards. The group included 38,220 workers who were exposed to low levels of radiation while on the job, and 32,510 nonexposed workers. The cancer death rate among the radiation-exposed shipyard workers (most of whom accumulated exposures of greater than 500 millirems) was lower than among the nonexposed workers and slightly lower than the rate for the U.S. white male population.

The rate for leukemia, specifically, was slightly lower than expected—both among the exposed and nonexposed shipyard workers. In addition, the overall death rate among radiation-exposed shipyard workers was significantly lower than the rate for U.S. white males.

The last finding is not unexpected, since worker populations in general tend to have

below-average mortality rates. This is because workers must be healthy to be hired, and they must remain healthy to continue their employment.

Stewart-Kneale Studies. British epidemiologists Alice Stewart and George Kneale published 1977, 1981 and 1993 studies on the effects of low radiation doses on workers at DOE's Hanford, Wash., nuclear complex. The 1981 analysis covered workers who died no later than 1977. The 1993 analysis included deaths from 1944 through 1986.

Among the questionable 1993 findings: 200 of the workers died or will die from radiation-induced cancer; older workers were at greater risk than younger workers; and radiation doses as low as that from natural background may be more harmful than implied in current radiation exposure standards for workers and the public.

Questions raised about the study's validity include:

- First, a 1992 study by the U.K. Radiological Protection Board of 95,000 nuclear power plant workers—who had received greater occupational doses than the Hanford employees—showed no excess cancers whatever.
- Second, Stewart and Kneale's results could have been marred by a flaw in their previous studies, in

Radiation Safety at Nuclear Power Plants: Studies Look at Public, Workers

Page 8 of 8—October 2003

which they ignored exposures of workers to potential carcinogens besides radiation.

- Third, if doses as small as those in the Stewart study affected cancer rates, then five million residents of Colorado, where the natural radiation level is high because of the altitude, should show 50,000 excess cancer deaths over their lifetime. But between 1950 and 1988, Colorado residents experienced fewer—not more—leukemia deaths than people at sea level.

Gilbert Study. In a 1993 study published in *Radiation Research*, Hanford epidemiologist Ethel Gilbert found fewer cancer deaths in radiation workers than in non-radiation workers. More important, her analysis showed no increase in cancer mortality with higher worker doses.

This fact sheet is also available at www.nei.org, where it is updated periodically.